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Psycho-Motor and Error Enabled Simulations:
Modeling Vulnerable Skills in the Pre-Mastery

PRINCIPAL INVESTIGATOR:
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14. ABSTRACT
This initial term of the grant has been focused on planning data collections and identifying key differentiating performance factors in the pre-mastery and mastery phases. Identifying these factors was primarily done by assessing major errors in simulating a laparoscopic ventral hernia repair. Additional simulation stations were added to the standards and purchases (including a motion tracking system) were completed. Two pilots were performed to assist in development of protocols, surveys and best practices.

15. SUBJECT TERMS Development of error framework for laparoscopic ventral hernia; Incorporation of error-based simulators into an exit assessment of chief surgical residents; Development of additional simulation stations and participant surveys; Purchasing: motion monitoring system, virtual reality equipment; Completion of two pilot tests

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Introduction

The initial term of the grant has been focused on identifying key differentiating performance factors in the pre-mastery and mastery phases. Identifying these factors was primarily done by assessing major errors in simulating a laparoscopic ventral hernia (LVH) repair. Based on collected data, the lab worked to finalize the incorporation of error-based simulators into an exit assessment of chief surgical residents.
The lab also focused heavily on planning data collections with the LVH assessment and additional simulation stations that were added for range of clinical and procedural skills in the simulated setting. The decision to purchase a motion tracking system to allow the lab to analyze participants hand movements as they perform the simulated tasks was completed. Finally, two pilots were performed to assist in development of protocols, surveys and best practices.

Summary for Statement of Work Progress

The following section details each element of the SoW as it has been addressed through our work thus far. For review, the following four objectives guided this work:
Objective One: To evaluate mental rehearsal as an intervention for skill decay in the pre-mastery phase.
Objective Two: To identify key differentiating performance factors for the pre-mastery and mastery phases.
Objective Three: To develop a generalizable, multi-variable, predictive model of skills decay.
Objective Four: To develop an efficient and effective set of assessment tools and individualized training recommendations to counteract skills decay.

In its first year, our work has largely focused on Objectives Two and Four because significant progress on these two objectives is required in order to address Objectives One and Three. We intend to continue refining the elements of Objectives Two and Four over the next year while our primary focus will shift towards addressing Objectives One and Three as data collection begins.

OBJECTIVE ONE

No progress at the time of this report. We plan to address this objective as data collection commences.

OBJECTIVE TWO

The greatest area of progress for Objective Two has been the development of an error framework for laparoscopic ventral hernia (LVH) repair and the research associated with it. Simulators and clinical scenarios were developed and incorporated into an exit assessment for chief surgical residents. The clinical scenario provided was for a “69 y/o male s/p exploratory laparotomy and bowel resection 1 year ago” (Figures 1 and 2).

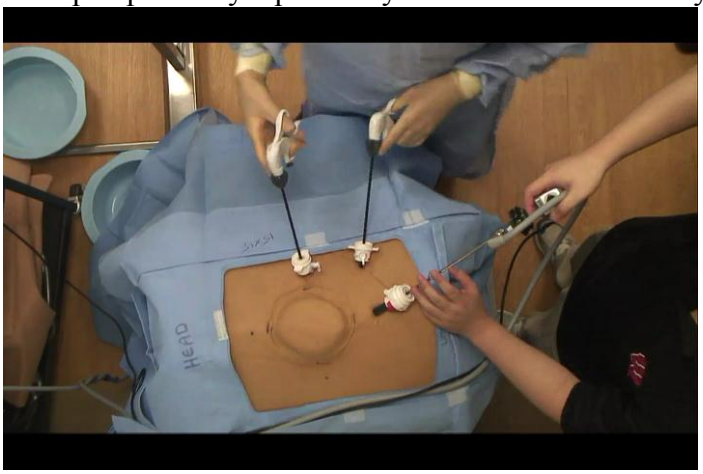

Figure 1 LVH Simulation Station

Development of error framework for laparoscopic ventral hernia repair

The team developed and refined an error framework for laparoscopic hernia repair. Data were analyzed from previously recorded resident performance on simulation based LVH repairs (Figure 2), and the team submitted abstracts to the American Surgical Association (ASA) (Pugh, C.M., Cohen, E.R., Law, K.E., Maag, A.D., Greenberg, J., Yen, T., Leigh, A.N., Greenberg, C., & Wiegmann, D., 2013) and American College of Surgeons –Accredited Education Institutes (ACS-AEI) (Maag, A.D., Law, K.E., Cohen, E.R., Greenberg, J., Kwan, C., Greenberg, C., Wiegmann, D., & Pugh, C.M., 2014). We were accepted for a podium presentation for the ACS-AEI meeting, but the ASA abstract was not accepted. Our data demonstrated that residents made more commission (71%) than omission errors (29%). Technical errors (64%) occurred more commonly than cognitive errors (36%); however, the latter were three times more prevalent than the former during the critical steps of the procedure as illustrated in the figure below.

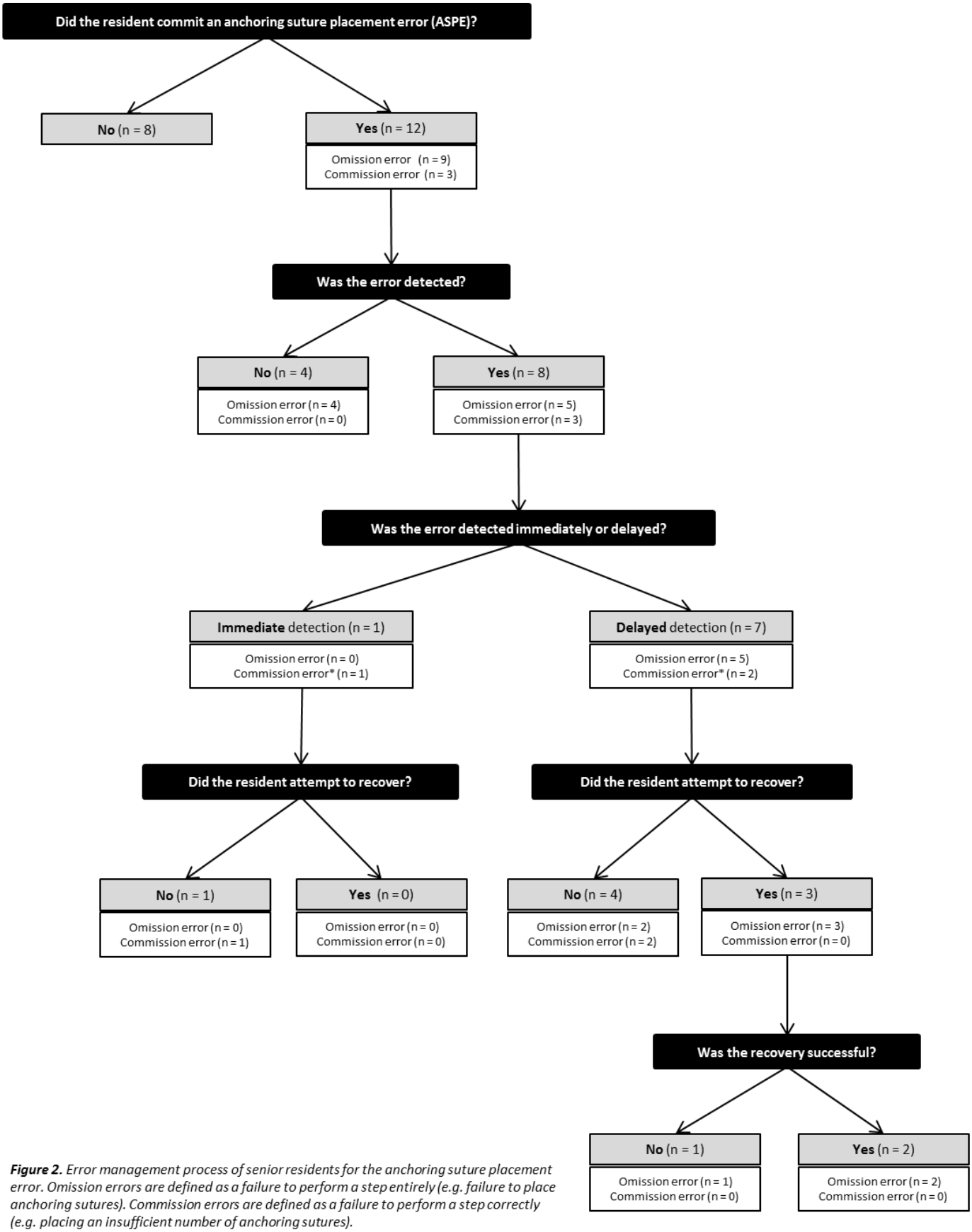

Figure 2. *Error management process of senior residents for the anchoring suture placement error. Omission errors are defined as a failure to perform a step entirely (e.g. failure to place anchoring sutures). Commission errors are defined as a failure to perform a step correctly (e.g. placing an insufficient number of anchoring sutures).*

* Team member detected error (n = 1)

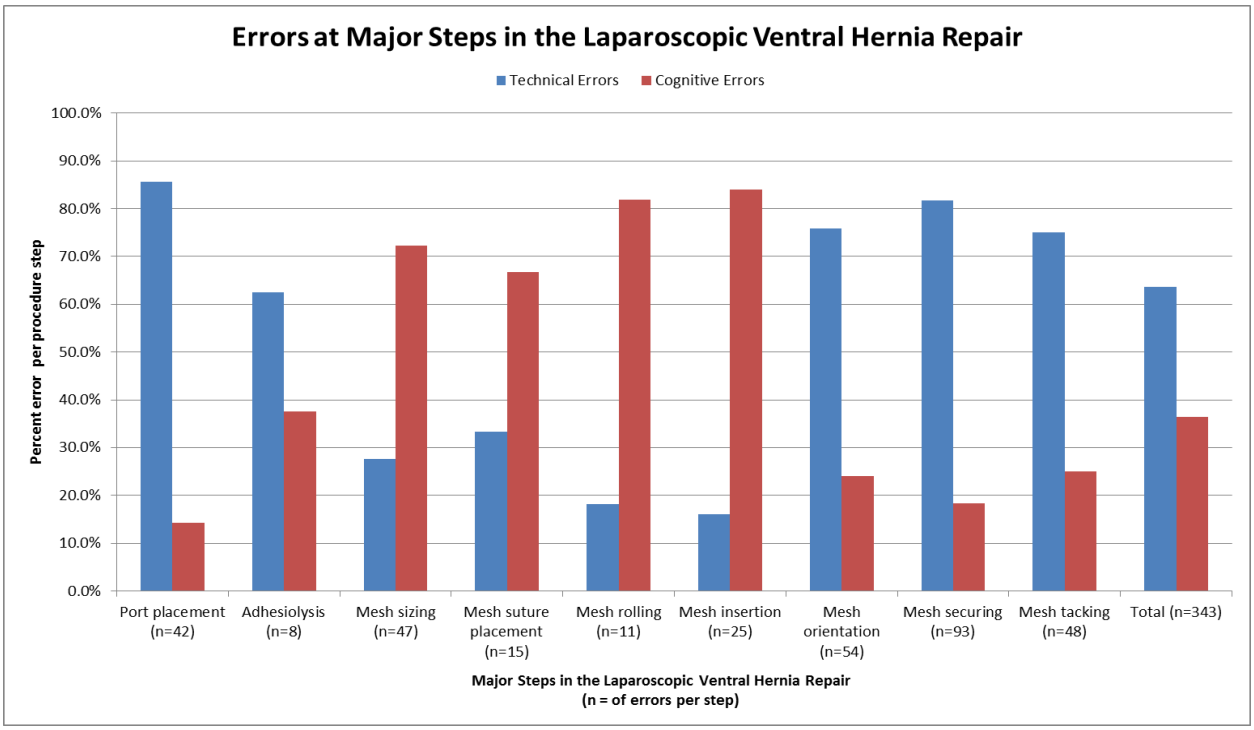

Figure 3 Note: Errors at major steps in the laparoscopic ventral hernia repair (LVH). Technical errors are defined as errors in action, procedure, or mechanical failures. Cognitive errors are defined as errors in information, diagnosis, and strategy.

Incorporation of error-based simulators into an exit assessment of chief surgical residents.
The exit exam for six chief resident surgeons assessed their skills at the completion of their residency training. Each station included an individual skills checklist based on the task given. These checklists were adapted from previously published works. In addition to the skills-specific checklists, each resident was evaluated using OSATS. A faculty rater observed each station and completed both the skills-specific and OSATS assessments for each resident. Residents also completed a baseline demographic and confidence survey (Appendix ref). After the simulations, residents participated in a focus group and discussed their experiences.
Chief residents performed an LVH repair, pancreaticojejunostomy and bowel anastomosis on Dr. Pugh's simulators. Data were analyzed and abstracts were sent to the Association for Surgical Education conference (accepted as podium presentation) and the American Hernia Society meeting (accepted as poster with distinction). Data demonstrated that specific checklist scores ranged from 58.3% to 100%. Analysis of OSATS ratings revealed that residents received the highest scores for instrument knowledge (4.78, SD=.43) and consistently lower scores for use of assistants (3.89, SD=.76). Final product analysis revealed a range of errors across all three procedures including incorrect technique and poor intra-operative planning leading to poor outcomes. Table 1 displays a portion of our results.

Table 1. ***Resident self-reported confidence and performance on skills checklist and OSATS for the three tasks***

Self-Report Item	LVH	Pancreaticojejunostomy	Bowel Anastomosis
Confidence in Readiness pre	4.00 (.63)	2.50 (.84)	4.33 (.52)
Confidence in Readiness post	4.00 (.63)	2.83 (1.17)	3.83 (1.17)
Skills checklist (%) correct	61.1% (25.1%)	82.3% (10.8%)	86.1% (13.1%)
OSATS Item			
Respect for tissue	4.67 (.82)	4.00 (.63)	3.58 (.80)
Time and motion	4.17 (.41)	3.83 (.75)	3.83 (1.03)
Knowledge of Instruments	4.83 (.41)	4.67 (.52)	4.83 (.41)
Use of assistants	4.00 (.89)	3.83 (.98)	3.83 (.41)
Flow of operation and forward planning	4.33 (.82)	4.12 (.98)	4.42 (.66)
Ability to adapt to individual pathological circumstances	4.00 (.63)	4.12 (.41)	4.00 (0)
Overall performance	3.67 (1.03)	3.75 (.88)	4.08 (.66)

OBJECTIVE THREE

No progress at the time of this report. We plan to address this objective as data collection commences.

OBJECTIVE FOUR

The predominant focus over the course of the past year has been in developing the assessment tools to be used in future data collection. The research team has taken significant strides towards completing these tools including (a) developing additional simulation stations and participant surveys for the study; (b) piloting, selecting, and receiving training on a motion tracking system from Innovative Sports Training that prepared the team to properly use the motion tracking system; (c) testing and selecting the appropriate virtual reality devices that would meet the grant's objectives; (d) completing two pilot tests of the simulation stations; and (e) hiring additional team members with expertise in lab management, motion tracking systems, and educational evaluation and assessment development.

A. Developing Additional Simulation Stations and Participant Surveys for the Study

Additional Simulation Stations

Three additional simulation stations and two VR stations were developed for the study in addition to the LVH simulation described under Objective Two. Specifically, bowel anastomosis, urinary catheterization, and subclavian central line placement simulations were created.

Simulators and clinical scenarios were developed and incorporated into an exit assessment for chief surgical residents. The bowel anastomosis simulator was designed for a mangled bowel procedure, representing a "28 y/o male s/p multiple gunshot wounds." Two injuries were made to explanted pig intestines, a large and a small bullet wound, and the participants were tasked with addressing the injuries (Figure 3). The urinary catheterization simulator presents participants with four unique scenarios, two males and two females, which each present a specific challenge to the catheterization procedure (Figure 4). Finally, the central line placement simulation again provides a descriptive case narrative that the participant reads prior to being observed placing the subclavian central line (Figure 5).

The VR stations were developed with consideration of testing participant psychomotor abilities. One station focuses on the abilities to detect applied forces and match those forces with precision. This station also involves scenarios where participants are presented with objects of differing stiffness and are forced to make a judgment regarding their perception of differences. The second station emphasizes a participant's ability to

precisely manipulate a tool through different spatial trajectories. In addition, participants are also presented with a scenario of recovering from errors forced on them by the robotic tool.

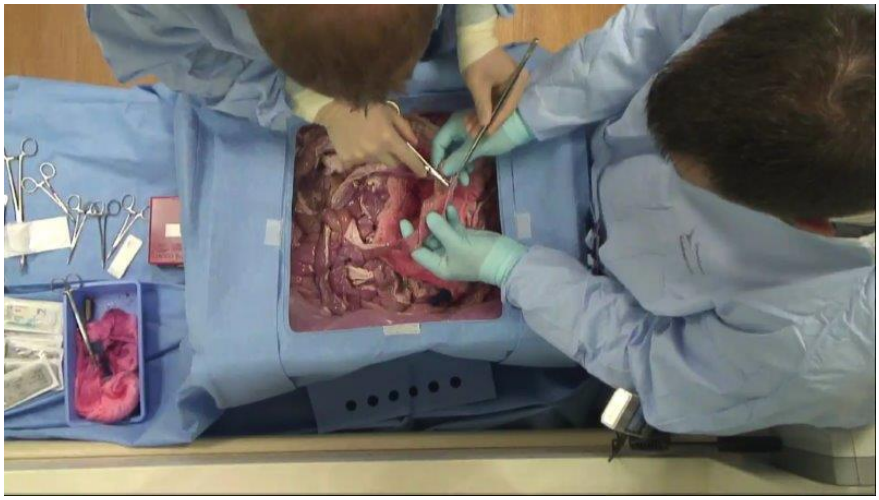

Figure 3 Bowel Anastomosis station

Figure 4 Urinary Catheterization station

Figure 5 Subclavian Central Line station

Participant Surveys

The team also developed a participant workbook that would be used throughout the stations (Appendix A). This workbook contained the self-report assessment instruments for the study as well as an opportunity to provide background demographic information and overall evaluation of the activity.

For each station, the participants would fill out two sets of brief, Likert-scale items in which they would indicate (1) their perceived confidence with each step of the procedure and (2) how difficult they anticipated each step the that procedure would be to complete. To gauge change from training experience, the participants filled out the instrument *both* before and after completing each procedure. An example for the LVH simulation is shown in the figure below. These instruments will continue to be refined as the study progresses.

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

Subject ID
(For office use only)

PRE-PROCEDURE
LAPAROSCOPIC VENTRAL HERNIA

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *before* beginning today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** do you anticipate it will be to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

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Figure 6.Example pre-procedure participant survey

B. Piloting, selecting, and receiving training on a motion tracking system from Innovative Sports Training that prepared the team to properly use the motion tracking system

Piloted motion capture technologies

The motion capture technologies were piloted in a study that aimed to develop a simulation-based system to evaluate psychomotor planning while suturing on different tissue types. The variable tissue simulator presents three different simulated tissue types: foam (dense connective tissue), rubber balloons (artery) and tissue paper (vein). The research team collected data from surgery faculty, residents, and medical students (N=15) on the variable tissue simulator designed to assess performance while suturing on material that simulated different types of tissue. There were significant differences in procedure time ($p < 0.001$), path length ($p < 0.001$) and idle time ($p < 0.005$) for the simulated tissues (Figures 7a and 7b). Attending surgeons (12.1m ± 2.8) had significantly shorter mean path lengths than medical students (19.5m ± 4.0) ($p = 0.021$). The following table displays our results and this were submitted as an abstract to the Society of Black Academic Surgeons conference.

Table 2. *Psychomotor Performance on Different Tissue Types*

Comparison	Mean (SD)			p – Value[1]
	Foam	Balloon	Tissue Paper	
Procedure time (s)	167.9 (53.1)	173.7 (53.2)	293.6 (87.9)*	< 0.001
Path length (m)	14.4 (4.6)	14.2 (4.4)	19.5 (6.2)*	< 0.001
Total idle time (s)	4.56 (3.54)	4.67 (3.28)	16.58 (13.86)*	< 0.005

[1]Groups compared using Analysis of Variance (ANOVA)

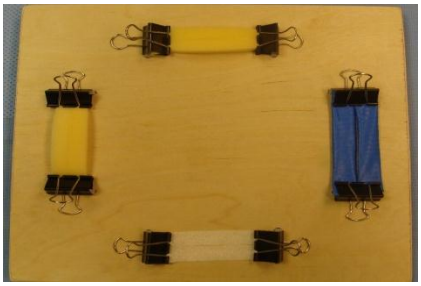

Figure 7a Variable tissue simulator setup

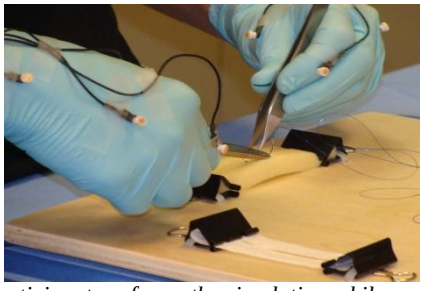

Figure 7b. Participant performs the simulation while wearing motion-capture sensors

The team traveled to Innovative Sports on 03/03/14 to view and accept purchase of the motion tracking devices. After the purchase was finalized, the motion tracking system was received at the lab on 03/11/14. To further prepare our team to use the system, Meredith Evans from Innovative Sports Training came to the lab on 03/20/14 to provide a second full day of training. Anne-Lise Maag, Calvin Kwan, Drew Rutherford, Patrick Barlow, Shannon DiMarco, and Shlomi Laufer were trained on the setup and usage of the system. Figure 8 below provides some examples of the system and the training that was obtained.

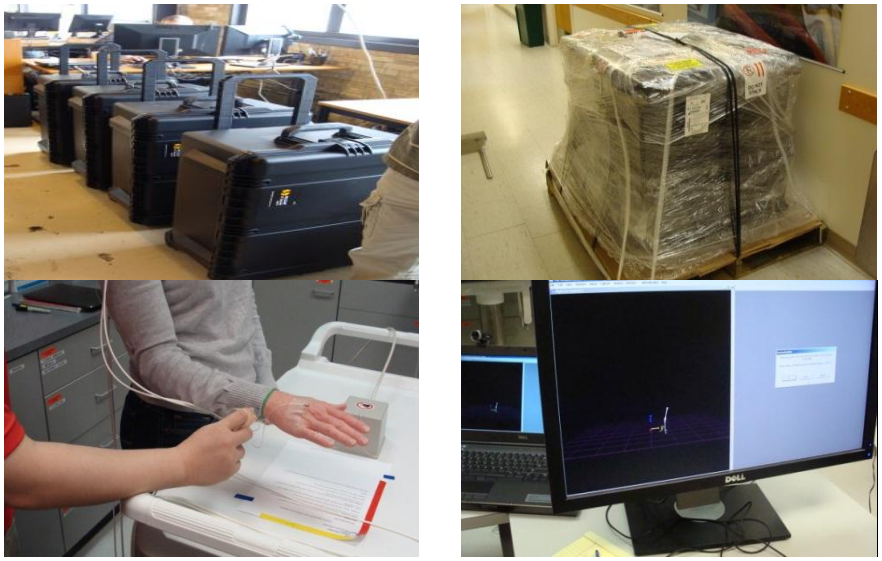

Figure 8. Images of purchasing and piloting the motion tracking system.

C. Testing and selecting the appropriate virtual reality devices that would meet the grant's objectives

Previously, a system had been selected that was well suited for our research goals; however, the team was unable to obtain this system. The team is now collaborating with Dr. Michael Zinn at the University of Wisconsin-Madison who is an expert in haptic and virtual reality systems. A choice was made to purchase one Force Dimension Omega Series haptic device (Figure 6a) as well as two GeoMagic Touch devices (Figure 6b) that will allow for monitoring of procedural skill performance on VR objects. Development and refining of the haptic VR tasks that will assess the residents' innate psychomotor skills is currently ongoing.

Figure 6a Force Dimension Omega Series device

Figure 6b GeoMagic Touch device

D. Completing Two Pilot Tests of the Simulation Stations

Pilot One: 03/12/14

The first pilot took place using two medical students who participated in testing at the stations. These students completed five of the six simulation stations, and motion tracking was performed for one of these stations. Furthermore, Dr. K Anders Ericsson was in attendance to provide immediate information and consultation on the Think Aloud protocol. Figure 9a – 9d offer examples of this pilot testing experience.

Figure 9a.. Participants work with the motion-tracking system

Figure 9b. Participant performs simulation while doing the Think Aloud protocol

Figure 9c. One participant performing the central line simulation

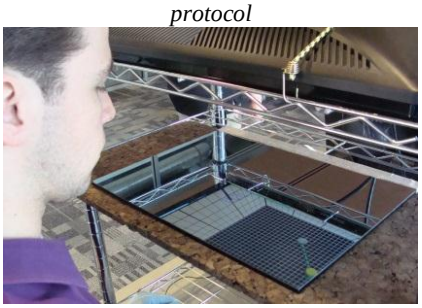

Figure 9d. An example of one of the two VR stations in progress

Three important challenges emerged from the first pilot test experience. These challenges and the way each was addressed prior to the second pilot test are listed below.

1. **Securing the motion tracking sensors to the participant**
    a. A modified lab coat was developed to secure the motion tracking sensors to the participant throughout the study (Figure 10). The coat used Velcro strips sewn into the sleeves and back, so that the lines could be securely attached to the body while still allowing for full range of motion.
2. **Time**
    a. More detailed protocols and methods for efficiently moving the participant through the stations were developed through meetings with the lab staff.
3. **Staffing the stations**
    a. Feedback from the first pilot informed the team that certain stations *must* include at least two team members such as the LVH station while others like the bowel anastomosis station could be managed with only a single team member.

Pilot Two: 03/31/14

The second pilot test took place on March 31st with four medical students performing each of the stations. This second pilot was used to implement the changes noted after the first one. First, the motion tracking system was fully implemented in the four error-enabled simulation stations (LVH, Urinary Catheter Placement, Bowel Anastomosis, and Central Line Placement) using our new approach to securing the motion tracking sensors to the participants (Figure 10a-b). Second, a single time-keeper was used who served as an announcer for when participants were supposed to move to a station, begin the procedure, and stop their work. Finally, staffing management was tested by having each station manager setup, run, and tear-down their own station, so feedback could be gathered on which stations could be successfully done with one rather than two team members.

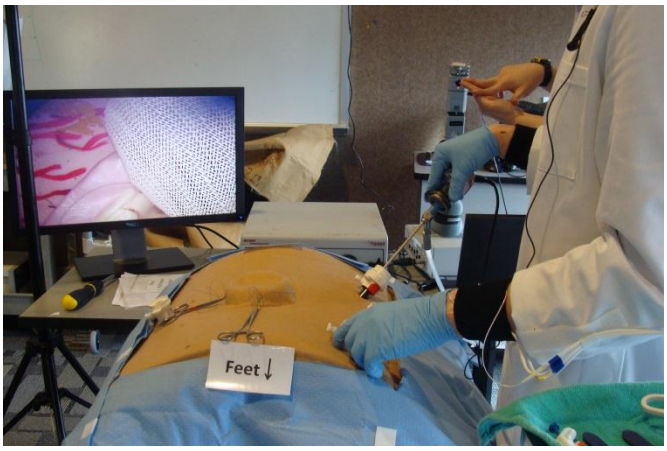

Figure 10a. The LVH station is piloted using motion-tracking

Figure 10b.A cropped photo of the new approach for affixing the motion-tracking sensors to the participant

A number of new challenges arose following the second pilot. The team particularly noted and addressed the following five challenges:

1. **Timing for stations** - Originally it was decided that each resident would get 20 minutes per data collection station: 2.5 minutes at the beginning to do pre-survey's and set up motion monitoring, 15 minutes to participate in the simulation and 2.5 minutes at the end to allow to unhook from the motion monitoring and completing the post-survey. This way all participants must get the exact same amount of time of data collection for each station; however, with motion tracking setup and station reset delaying the start times, another protocol will need to be determined and is being discussed.
    a. One specific change to the protocol has been instructing the participants to complete the pre-participation survey for *all* stations prior to beginning the activity. This change allows for additional time for setup at each station. Also among the solutions that have been proposed is preparing a specific setup protocol for research staff to connect participants in an assembly line fashion.
2. **Surveys** - Surveys must be organized in a way that are clear to both the participant and the researcher to easily flow from one station to the next; even if the stations are not in the same order as the surveys. Protocol changes have begun to ease the flow of these.
    a. The instruments have been revised to make a "Participant Workbook." This workbook contains an updated version of the instruments as well as a new organization strategy which places all of the pre-procedure questions *first*. The workbook also contains seven tabs, one for each station, so the participant can easily flip to the correct post-procedure survey no matter which order they complete the stations. Finally, a protective cover was added to the workbook to prevent accidental damage.
3. **Preparing residents** - Getting residents into jackets and suited with the motion tracking system will need to have a protocol for success.
    a. As noted above, this specific obstacle will need to be addressed, and solutions have been discussed.
4. **Staffing** - It was originally thought that only a few stations would need two people per day at the data collections; however with motion tracking and re-set up of each station, more staffing will be required..
    a. The current proposal is to use two individuals per clinical station and one at each VR station, which would bring the total required staff to 12 when the announcer/facilitator and additional support are added.
5. **Think Aloud Protocol** - A better protocol must be determined in order to successfully go through the steps of the Think Aloud. All researchers must be trained on this technique.
    a. Solutions to this obstacle are currently being discussed.

Additional Noteworthy Progression on Key Study Elements

Three additional vital components to the success of the grant are: the securing of ongoing ethical approval (1), the recruitment of human subjects as research participants (2), and hiring additional research staff (3). This next section provides an update on the progress the team has made with regard to these three components.

Progress of Securing of Ongoing Ethical Approval

The research team has been granted ongoing approval from the DoD institutional review board as well as the IRB from the University of Wisconsin. The most recent protocols were approved by the DoD 02/28/14 and by UW on 03/07/14. Additionally, a new protocol change has been submitted to the UW IRB 03/16/14 that includes details on compensating residents for their participation.

Progress of the Recruitment of Human Subjects as Research Participants

The team completed site visits at seven academic institutions: University of Wisconsin, Medical College of Wisconsin, Loyola University, Northwestern University, University of Chicago Medical Center, University of Illinois at Chicago, University of Illinois – Metro, University of Illinois – Mt. Sinai, Rush University Medical Center and University of Illinois College of Medicine (Table 3). The program director from each site is committed to this research study. The University of Minnesota and Mayo Clinic have also committed their involvement in this study. While conducting these site visits, team members met with program directors, program coordinators and other key personnel at the different institutions. The team also assessed physical space for the data collections and found suitable places at four institutions for the first data collection.

Another key area where the team has made progress is the recruitment of residents at various stages in their lab training. The current group sizes for lab years zero, one, two, and three are 18 (30.5%), 28 (47.5%), 9 (15.3%), and 4 (6.8%), respectively. In order to maintain approximately equal group sizes, a concerted effort to recruit additional late-year residents should be made.

Table 3. ***Progress on Subject Recruitment by Sample Site***

Site	Residents Currently On-Site[1]	Residents Currently Off-Site[2]	Number Committed for Data Collection Period			
			Summer 2014	Fall 2014	Summer 2015	Summer 2016
UW-Madison	11	2	12	9	9	3
Loyola	7	3	8	6	6	3
Mt. Sinai	1	0	1	0	0	0
UIC	0	4	2	1	1	0
University of Chicago	-	-	12	7	7	3
Metro	1	-	1	0	0	0
Northwestern	10	3	11	7	7	5
Mayo	10	-	0	6	6	4
All Sites[3]	**40**	**12**	**47**	**36**	**36**	**18**

[1,2]: "-" indicates the site has not provided this information.

[1]Totals reflect those residents who have committed by the time of this report. The University of Minnesota, Rush, and MCW sites have committed to participating in the study; however, the data for specific residents were not yet provided to the research team.

The team also began working towards finalizing the start of data collection by streamlining the process for gathering data from multiple sites at one time. For example, the summer 2014 data collection from the schools in the Chicago area will be held in a large space that was donated to the study by Loyola University (Figure 11). Additional planning is still in process.

Figure 11. Two images of the data collection space at Loyola University.

Additional Staffing (Patrick Barlow, Drew Rutherford, Katherine Law, and Shannon DiMarco)

Four additional staff members have been added to the research team over the course of the last year. Each of these members bring specific backgrounds and expertise to the team, which will overall assist with addressing the grant's objectives. A brief description of each new member as well as their role in the project is provided below.

Patrick Barlow, PhD: Dr. Barlow received his PhD in Educational Psychology and Research with a concentration in Evaluation, Statistics, and Measurement from the University of Tennessee-Knoxville. His specific role in the project will be assisting with the development of all assessment, survey, and evaluation instruments for the project.

Drew Rutherford: Drew is seeking a Master's of Science in Kinesiology (Motor Behavior and Control emphasis) from University of Wisconsin-Madison. Specializing in hardware management and data analysis protocols, Drew is assisting in the purchase of the motion tracking device and the development of the virtual reality stations.

Katherine Law: Katie Law is a PhD student in the Department of Industrial and Systems Engineering at the University of Wisconsin-Madison. She is working on evaluating resident performance on simulators under this grant.

Shannon DiMarco: Shannon, BA, was hired as an Associate Administrative Program Specialist Lab Manager. She specializes in organizing protocol, budgeting and purchasing.

Key Research Accomplishments

Table 4 provides a bulleted list of the project accomplishments as organized by the quarter they were achieved. Additional information such as research citations and specific achievement dates have been provided whenever they were available.

Table 4. ***List of Project Accomplishments per Quarter***

#	Task	Quarter
1	Began development of an error framework for laparoscopic ventral hernia repair.	One
2	Piloted mangled bowel simulation and laparoscopic ventral hernia repair simulation at two venues, one involving experienced general surgeons and one involving chief resident surgeons.	One
3	Met with collaborators to begin assessment of motion tracking technologies.	One
4	Submitted an IRB protocol for the entire project to the DOD for pre-review 02/23/13. This has been reviewed and preliminarily approved by the DOD to submit to UW IRB. Phase 1 of the IRB has been submitted to the UW Health Sciences IRB and has gone under preliminary review. Edits are currently being made.	Two
5	Developed a robust preliminary error framework for laparoscopic ventral hernia repair, and we are currently using that framework to assess videos of simulation based LVH procedures.	Two
6	Completed the analysis of the pre-existing Trauma Surgeon Quality & Team Improvement data and are now in the process of writing a paper.	Two
7	Completed development of a box-trainer type error-enabled procedure simulation for laparoscopic ventral hernia and the first iteration of a mangled bowel anastomosis.	Two
8	Analyzing central line data from an ongoing hospital based project that will facilitate development of new central line scenarios for this project.	Two
9	The principal investigator, co-investigators and key personnel met on June 26 to review specific aims, logistics, and timeline, and made decisions regarding purchases of equipment and supplies. Over 13 research team members were present for this kick-off meeting.	Two
10	Selected a portable head-tracked haptic VR simulator that offers many one-of-a-kind haptics and physics capabilities. This technology is well suited to the grant's research goals.	Two
11	Purchased bladder catheterization and central line placement models.	Two
12	Begun to pilot test motion tracking technologies.	Two
13	Submitted and revised UW Health Sciences IRB. Projected approval January 2014.	Three
14	Developed error framework for laparoscopic ventral hernia (LVH) repair. We implemented this framework to categorize resident error detection and management while performing a simulated LVH repair from pre-existing video-recordings.	Three
15	Analyzed data from error framework and submitted two abstracts: one to the American Surgical Association and the other to the American College of Surgeons –Accredited Education Institutes.	Three
16	Analyzed performance of chief residents on clinical scenarios and simulators that were incorporated into an exit assessment. The abstract we submitted to the Association for Surgical Education was accepted for an oral presentation and the abstract we submitted to the American Hernia Society was accepted for a poster presentation with distinction.	Three

Table 4. ***List of Project Accomplishments per Quarter***

#	Task	Quarter
17	A manuscript entitled: *Core Challenges in Implementing Organizational Change and Quality Oversight at a Level - 1 Trauma Center* was submitted to the Journal of the American College of Surgeons (JACS) in January. Results from this data analysis are presented as part of a research paper presenting a global analysis of team skills. In the study, 10 surgeons taking trauma call from a tertiary university hospital were video recorded during a potential skills decay situation. The data demonstrated that sophisticated models of human error analysis facilitate intraoperative performance evaluations and serve as a blueprint for developing curricular interventions to improve readiness, error detection and error management.	Three
18	Purchased four customized motion capture and analysis systems from Innovative Sports Training. This will be used to collect kinematic performance data from participants completing error-enabled procedure simulations (laparoscopic ventral hernia, urinary catheterization, bowel anastomosis and central line placement).	Three
19	Completed development of our error-enabled simulation for the laparoscopic ventral hernia repair and have undergone iterations of the mangled bowel anastomosis.	Three
20	Collaborated with UW Veterinary Diagnostic Laboratory to develop a preservation solution for the bowel anastomosis error-enabled procedure simulation.	Three
21	Ordered and received a new urinary catheterization simulator.	Three
22	Analyzed data from the pilot of motion tracking technologies and submitted an abstract to the Society of Black Academic Surgeons conference.	Three
23	Began collaborating with Dr. Michael Zinn for the development of a haptics-enabled, virtual reality system for assessment of innate psychomotor skills.	Three
24	The team is in the process of purchasing of a haptic system.	Three
25	Performed site visits at University of Wisconsin, Medical College of Wisconsin, Loyola University, Northwestern University, University of Chicago Medical Center, University of Illinois at Chicago, University of Illinois – Metro, University of Illinois – Mt. Sinai, Rush University Medical Center and University of Illinois College of Medicine.	Three
26	The program director at each of these above sites is committed to the research project.	Three
27	Established a commitment from the University of Minnesota and the Mayo Clinic in this research study and are in the process of scheduling site visits for these locations.	Three
28	The team is in the process of planning a meeting with Dr. Anders Ericsson for collaboration on the development of verbal protocols for collection of qualitative data from resident performance on the error-enabled simulations.	Three
29	Collaborated with experts to develop the Think Aloud protocol	Four
30	Tested and accepted purchase of motion tracking on 03/03/14	Four
31	Received motion tracking system on 3/11/14	Four
32	Received training from Innovative Sports on motion tracking system 03/20/14	Four
33	Developed protocol to execute motion tracking system	Four
34	Pilot on 03/12/14 was assessed by Dr. K. Anders Ericsson	Four
35	Purchased and obtained two GeoMagic Touch devices	Four
36	Purchased and obtained Force Dimension haptic device	Four
37	Developed scenarios for all stations	Four
38	Developed protocol for set up and execution of each station	Four
39	Establishing times for residents to do their first data collection in May, June or July.	Four
40	Second pilot took place on 03/31/14	Four

Reportable Outcomes

Table 5 provides a bulleted summary of the reportable outcomes achieved over the past year. These outcomes include specific methodological improvements, new prototypes such as the…, and also specific products such as conference presentations, research papers, assessment instruments, and research protocols. Specific citations have been provided when appropriate.

Table 5. ***List of Reportable Outcomes per Quarter***

#	Type	Outcome	Quarter
1	Methodology	Developed a robust preliminary error framework for laparoscopic ventral hernia repair, and we are currently using that framework to assess videos of simulation based LVH procedures.	Two
2	Prototype	Completed development of a box-trainer type error-enabled procedure simulation for laparoscopic ventral hernia and the first iteration of a mangled bowel anastomosis.	Two
3	Product	Visited the company Innovative Sports Training in Chicago, IL and worked with this company to develop a customized motion capture and analysis system. This integrated system is currently being constructed by Innovative Sports Training with estimated deliverable date in early February, 2014.	Two
4	Methodology	Developed and refined the error framework for laparoscopic ventral hernia repair and are continuing to using this framework to assess videos of simulation based LVH procedures.	Three
5	Methodology	Completed a motion tracking pilot with surgical attendings, residents, and medical students (N=15) and are developing a methodology for analyzing kinematic data for clinical skills performance assessment.	Three
6	Product	Purchased and received (03/11/14) the motion tracking systems from Innovative Sports Training.	Four
7	Product	Developed a participant workbook that contains all of the revised survey assessment instruments for the study.	Four
8	Prototype	Developed prototypes for the virtual reality stations. These stations were piloted both on 03/12/14 and 03/31/14.	Four
9	Product	Submitted *Use of Error Analysis to Assess Resident Performance* and the team is currently in the process of writing *two* additional manuscripts.	Four

Final Conclusions

Year one of the project has included a number of significant steps towards meeting the four key study objectives outlined by our original SoW. Specifically, the team developed a robust error framework for laparoscopic ventral hernia repair; developed five additional simulation stations for our primary data collection; purchased or developed all of the necessary technical equipment for the study; successfully completed two pilot trials of the data collection process; and disseminated our preliminary work in the form of several papers and presentations. Although there have been challenges in recruitment efforts, the team has been successful in securing commitment from 10 different sites ($N_{\text{residents}} \approx 40$).

References for Abstracts Submitted as Part of this Project

ASA abstract (rejected)
Pugh, C.M., Cohen, E.R., Law, K.E., Maag, A.D., Greenberg, J., Yen, T., Leigh, A.N., Greenberg, C., & Wiegmann, D. (November 2013). Resident readiness for independence: An analysis of intraoperative error management in a simulated setting. Submitted to the annual meeting of the American Surgical Association. Rejected.

ACS-AEI (accepted-presented)
Maag, A.D., Law, K.E., Cohen, E.R., Greenberg, J., Kwan, C., Greenberg, C., Wiegmann, D., & Pugh, C.M. (2014). Use of Error Analysis to Assess Resident Performance. Oral presentation given at the annual consortium of the American College of Surgeons-Accredited Education Institutes.

ACS-AEI (manuscript- submitted, awaiting response)
Maag, A.D., Law, K.E., Cohen, E.R., Greenberg, J., Kwan, C., Greenberg, C., Wiegmann, D., & Pugh, C.M. (2014). Use of Error Analysis to Assess Resident Performance. Submitted to the journal Surgery.

SBAS (accepted-poster)
Maag, A.D., Rutherford, D.N., Laufer, S., Kwan, C., Cohen, E.R., Pugh, C.M. (2014). The variable tissue simulator: Validation of a quantitative model of intra-operative decision making. Planned poster presentation at the annual meeting of the Society of Black Academic Surgeons, April 2014.

ACS (abstract-submitted awaiting response)
Pugh, C.M., Cohen, E.R., Law, K.E., Maag, A.D., Greenberg, J., Yen, T., Leigh, A.N., Greenberg, C., & Wiegmann, D. (2014). Resident readiness for independence: An analysis of intraoperative error management in a simulated setting. Submitted to the annual meeting of the American College of Surgeons.

ASE (abstract accepted-oral presentation planned 4/10)
Maag, A.D., Cohen, E.R., Kwan, C., Laufer, S., Greenberg, C., Greenberg, J., Wiegmann, D., Pugh, C.M. (2014). Use of decision-based simulations to assess resident readiness for operative independence. Oral presentation given to the annual meeting of the Association for Surgical Education.

Maag, A.D., Cohen, E.R., Kwan, C., Laufer, S., Greenberg, C., Greenberg, J., Wiegmann, D., Pugh, C.M. (2014). Use of decision-based simulations to assess resident readiness for operative independence. Manuscript in preparation with planned submission to the American Journal of Surgery.

Appendix A: Copy of Participant Assessment Workbook

(Current 04/07/2014)

Subject ID
(For office use only)

STUDY TITLE
PARTICIPANT WORKBOOK

Sample Logo

GENERAL INSTRUCTIONS: Use this space to write general instructions about filling out the workbook & moving through the stations.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

PRE-PARTICIPATION SURVEY
BACKGROUND INFORMATION

Directions: As part of today's activity, we will be asking you to fill out a brief survey about your experiences both *before* and *after* you have completed the activity. Please fill out pages one and two ***before*** beginning any of the procedures. Then, you will complete a short survey before and after each station. Finally, there will be an overall exit survey to complete when you have finished with all of the stations. Thank you!

1. What is your gender?
   - Male ☐
   - Female ☐
   - Prefer not to answer ☐

2. What is your dominant hand?
   - Left ☐
   - Right ☐
   - Ambidextrous ☐

4. Do you have a latex allergy?
   - Yes ☐
   - No ☐

3. What is your ***smallest*** glove size? (please write a number) _____

5. Estimate the time you have been or will be engaged in the following: (please write a number)

   Clinical years ***prior*** to entering the lab _____

   Months spent ***in the lab*** until now _____

   Total number of months you ***plan to stay*** in the lab _____

Turn to the next page

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

PRE-PROCEDURE

LAPAROSCOPIC VENTRAL HERNIA

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *before* beginning today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** do you anticipate it will be to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

Turn to the next page

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
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PRE-PROCEDURE
BOWEL ANASTOMOSIS

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *before* beginning today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Prepare the injured bowel	☐	☐	☐	☐	☐
Select the correct suture	☐	☐	☐	☐	☐
Select the correct stitch	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** do you anticipate it will be to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Prepare the injured bowel	☐	☐	☐	☐	☐
Select the correct suture	☐	☐	☐	☐	☐
Select the correct stitch	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

Turn to the next page

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

PRE-PROCEDURE
Urinary CATHETERIZATION

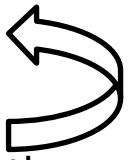
Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *before* beginning today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Identify relevant anatomy	☐	☐	☐	☐	☐
Problem solve if you encounter difficulty inserting the catheter	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** do you anticipate it will be to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Identify relevant anatomy	☐	☐	☐	☐	☐
Problem solve if you encounter difficulty inserting the catheter	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐



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WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

PRE-PROCEDURE
SUBCLAVIAN CENTRAL LINE INSERTION

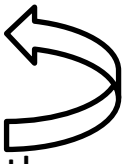
Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *before* beginning today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Identify appropriate landmarks	☐	☐	☐	☐	☐
Cannulate the subclavian vein	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** do you anticipate it will be to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Identify appropriate landmarks	☐	☐	☐	☐	☐
Cannulate the subclavian vein	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐



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WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

PRE-SCREENING FOR VIRTUAL REALITY STATIONS

Subject ID (For office use only)

Directions: Before you take part in the virtual reality station, please take a minute to provide some information about any previous experience you may have had with virtual environments (VE). Please answer each of the following questions by selecting the ***frequencies*** that reflect you experiences over a "typical" or "average" month.

During an average month I…	Never	About Once Per Month	About Once Per Week	Almost Daily
Have headaches	☐	☐	☐	☐
Have blurred vision	☐	☐	☐	☐
Have dizziness with my eyes ***open***	☐	☐	☐	☐
Have dizziness with my eyes ***closed***	☐	☐	☐	☐
Have vertigo (spinning of the world while I am still)	☐	☐	☐	☐
Have motion sickness	☐	☐	☐	☐
Feel faint	☐	☐	☐	☐
Feel like vomiting	☐	☐	☐	☐
Feel nauseous	☐	☐	☐	☐

About how many hours in ***an average*** *week* do you typically play video or computer games?

- I do not play video or computer games ☐
- 1 – 5 hours ☐
- 6 – 10 hours ☐
- 11 – 15 hours ☐
- 16 – 20 hours ☐
- Over 20 hours ☐

Have you ever been exposed to a 3D computer environment?

- Yes ☐
- No ☐

If yes, did you experience sensations of nausea or dizziness as a result of that experience?

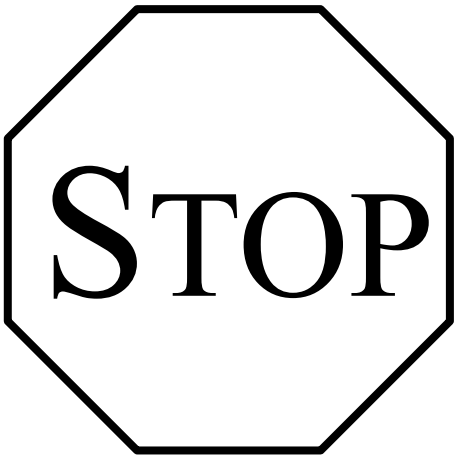
- Yes ☐
- No ☐

Subject ID
(For office use only)

Directions: Please listen to the announcements in order to complete each of the procedure stations. You will then have an opportunity to fill out a post-procedure survey after each station. Use the next section of this workbook to complete your post-procedure surveys.

Key Reminders for Today's Activity:

1. The announcer will tell you when to move to a new station, when to begin your procedure, and when to stop working.
2. You will be given 15 minutes to complete the procedure at your station to the best of your ability.
3. You will turn to the procedure's post survey (tab) once the announcer tells you it is time to stop working.
4. If you have any questions, please do not hesitate to ask!



Do not turn to the next section until you have completed your first procedure station.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

POST-PROCEDURE
LAPAROSCOPIC VENTRAL HERNIA

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *after* performing today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** was it to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Plan proper port location	☐	☐	☐	☐	☐
Completely visualize hernia defect	☐	☐	☐	☐	☐
Measure the hernia defect	☐	☐	☐	☐	☐
Plan mesh deployment and attachment	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

What additional comments do you have about this station?

NEXT

Please move to the next station when the announcer tells you to go.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

POST-PROCEDURE
BOWEL ANASTOMOSIS

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *after* performing today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Prepare the injured bowel	☐	☐	☐	☐	☐
Select the correct suture	☐	☐	☐	☐	☐
Select the correct stitch	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** was it to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Prepare the injured bowel	☐	☐	☐	☐	☐
Select the correct suture	☐	☐	☐	☐	☐
Select the correct stitch	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

What additional comments do you have about this station?

NEXT

Please move to the next station when the announcer tells you to go.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

POST-PROCEDURE
Urinary CATHETERIZATION

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *after* performing today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Identify relevant anatomy	☐	☐	☐	☐	☐
Problem solve if you encounter difficulty inserting the catheter	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** was it to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Identify relevant anatomy	☐	☐	☐	☐	☐
Problem solve if you encounter difficulty inserting the catheter	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

What additional comments do you have about this station?

NEXT

Please move to the next station when the announcer tells you to go.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

POST-PROCEDURE
SUBCLAVIAN CENTRAL LINE INSERTION

Directions: Please ☒ the box that best describes your opinion of your ability to perform each step of the following surgical tasks *after* performing today's simulation.

How ***confident*** are you in your ability to perform each of the following procedure steps?

	Not Confident	Somewhat Confident	Moderately Confident	Very Confident	Extremely Confident
Identify appropriate landmarks	☐	☐	☐	☐	☐
Cannulate the subclavian vein	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

How ***difficult*** was it to perform each of the following procedure steps?

	Not Difficult	Somewhat Difficult	Moderately Difficult	Very Difficult	Extremely Difficult
Identify appropriate landmarks	☐	☐	☐	☐	☐
Cannulate the subclavian vein	☐	☐	☐	☐	☐
Successfully perform the entire surgical task	☐	☐	☐	☐	☐

What additional comments do you have about this station?

NEXT

Please move to the next station when the announcer tells you to go.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

POST-PROCEDURE FOR VIRTUAL REALITY STATIONS

Directions: Now that you have completed the virtual reality stations, please ☒ the box that best describes your ability to perform certain aspects of the virtual reality station from 1 = "Very poor" to 5 = "Excellent." If you are unsure of a certain statement, then please select "Unsure."

How would you rate your ability to…?	Very Poor	Poor	Fair	Good	Excellent	Unsure
Orient yourself to the virtual environment viewpoint	☐	☐	☐	☐	☐	☐
Manipulate the device handle for your target goals	☐	☐	☐	☐	☐	☐
Discriminate between different degrees of stiffness	☐	☐	☐	☐	☐	☐
Maintain desired position of the virtual stylus (cursor)	☐	☐	☐	☐	☐	☐
Detect the direction of applied forces	☐	☐	☐	☐	☐	☐
Compensate for the application of forces	☐	☐	☐	☐	☐	☐

What additional comments do you have about these stations?
VR Station One: "Handle Device" Virtual Reality Station

VR Station Two: "Stylus and Mirror" Virtual Reality Station

NEXT

Please move to the next station when the announcer tells you to go.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

FINAL EXIT SURVEY

Directions: Thank you for participating in today's research! We would like to ask you to please take the last few minutes of today's activity to tell us about your overall experience. Feel free to use the back of this sheet if you have additional comments.

Please ☒ the box that best describes your opinion of each statement.	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I knew what was expected of me at each station.	☐	☐	☐	☐	☐
The clinical scenarios at each station were realistic.	☐	☐	☐	☐	☐
The simulation activities were realistic.	☐	☐	☐	☐	☐
I had enough time to complete each station.	☐	☐	☐	☐	☐
I learned something new today.	☐	☐	☐	☐	☐
The research staff was able to answer my questions.	☐	☐	☐	☐	☐
I would recommend this activity to other residents at my institution.	☐	☐	☐	☐	☐

What was your favorite part of today's activity?

What was the greatest challenge you encountered during today's activity?

In what ways could we improve today's activity to make it more useful for future residents?

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Subject ID
(For office use only)

Please use this space for any additional comments you have about your experience here today.